National Aeronautics and Space Administration

Office of Space Science

MEETING REPORT

SPACE SCIENCE ADVISORY COMMITTEE

February 29 – March 2, 2000

NASA Headquarters
Washington, DC

Dr. Steven W. Squyres	Dr. Jeffrey D. Rosendhal
Chair	Executive Secretary

SPACE SCIENCE ADVISORY COMMITTEE (SScAC)
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Meeting Minutes

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MEETING OF THE
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Tuesday, February 29:

Opening Remarks/Announcements

Committee Chair Dr. Steven Squyres called the meeting to order and welcomed the participants. He introduced new member Dr. Michael Drake who is replacing Chris Chyba as Chair of the Solar System Exploration Subcommittee (SSES). He noted that, as a consequence of the Galveston Strategic Planning Workshop, this was the first SScAC meeting in 8 months and that there were many important subjects to be covered. Following a review of the agenda and a discussion of possible dates for the next two meetings, Dr. Squyres introduced the presentation on the Office of Space Science's program and budget status by offering the Committee's congratulations on the recent successful Hubble Repair Mission.

OSS Program Status/FY 2001 Budget Proposal

Associate Administrator Edward J. Weiler briefed the Committee on the status of the Space Science (OSS) program and on the budget that has been proposed by the President for the coming fiscal year. He started off by noting that the successful Hubble Repair Mission followed the two Mars mission failures and has been critical in helping to rebuild morale at NASA Headquarters. The New Year's present received from Office of Management and Budget (OMB) also helped in restoring morale. There have been many other successes as well. Dr. Weiler presented a collage of results from the Chandra X-ray Observatory and noted that the extra $50 million OSS spent in delaying the launch was critical in assuring the success of the mission being enjoyed now. Spending the extra money to assure mission success was the right thing to do and shows that OSS is paying attention to the "Better" part of Faster-Better-Cheaper. The Mars Global Surveyor continues to produce excellent results (laser altimeter data suggesting the existence of an ancient Martian shoreline were used to illustrate the point) as does the Galileo mission which is still surviving Jupiter's radiation field. Galileo will be kept going as long as it continues to make sense to do so. TRACE continues to produce spectacular images of the Sun and results from both TRACE and the Solar Heliospheric Observatory (SOHO) have recently been featured on the evening news. The Near Earth Asteroid Rendezvous (NEAR) spacecraft is currently orbiting the asteroid EROS and has already returned some remarkable images.

Dr. Weiler began his review of the status of the OSS program by noting that all missions scheduled for launch in 1999 by NASA were successfully launched (however both the WIRE and TERRIERS missions subsequently failed on-orbit), and that those currently under development were, with a few key exceptions, doing well. Missions experiencing significant problems would be discussed individually. The launch of the Japanese Astro-E mission (which had a significant contribution from NASA) on a Japanese launch vehicle was a failure and the spacecraft was destroyed—a major setback for X-ray astronomy. A failure of one of the gyroscopes on the Compton Gamma Ray Observatory (CGRO) is likely to mean that it will have to be de-orbited, even though it is still working well, to avoid a later uncontrolled re-entry. The spacecraft is very heavy and the fundamental issue is one of public safety if there were to be an uncontrolled reentry. He said that alternatives

to de-orbit were being explored and that a decision would be announced in March following a comprehensive review of the situation. Dr. Weiler noted that a number of minor technical problems associated with the IMAGE mission were being addressed and that the launch would be delayed. However, lengthy delays were not expected.

Dr. Weiler stated that the major issues he was currently dealing with were the restructuring of the Mars Program and serious technical problems encountered in the Gravity Probe-B (GP-B) development. With regard to the Mars Program, there are both near-term and long-term issues that need to be addressed. In the near-term, decisions have to be made as to how (or whether) to proceed with the Mars '01 Orbiter and Lander. More fundamentally, the whole Mars architecture, including the approach to sample return, is being reexamined. A number of committees have been reviewing various aspects of the Mars Program. In particular, the Young committee has been putting in very long hours and is expected to issue its report on March 15th, with a NASA press conference to say how the Agency would respond soon after. Results from all of these reviews will attract strong congressional interest, and there will be a number of congressional hearings on the subject of the Mars Program. Weiler noted that the Young committee's charge was not to evaluate the science of the Mars Program but rather to look at the management process and to find out the lessons to be learned from the failures that need to be incorporated into a restructured program. Weiler said that, at this point, he would prefer a slower, more cautious approach to Mars exploration. The program can't afford any more failures, and he would rather do Mars exploration slower and do it right than do it faster and wrong. In response to questions, Weiler indicated that uncertainties in budget estimates would be dealt with by having adequate program reserves and that schedules would also be adjustable. Missing a launch opportunity will not be the end of the world if it means the difference between failure and success.

With respect to GP-B, Dr. Weiler said that there were major schedule and budget problems. There have been failures of critical components (including the cryogenic system) during tests and the root causes of these failures are still not known. A review committee chaired by Parker Stafford reported its results last week, and, among other things, indicated that the management of the program needs to be significantly strengthened. Dr. Weiler indicated that there were several options for proceeding with GP-B and dealing with the associated cost increases (all of which had significant consequences for other parts of the OSS program) or he could begin the process for terminating the mission. Since no new funds would be required in FY 2000 to deal with GP-B problems, a decision on what to do could be delayed until the summer when better information would be available on problems and costs. New resources (up to $65M) will be required in FY 2001 and 2002 if the mission were to continue. In view of the potential impact on other programs, cancellation is still an option. He would welcome advice from SScAC as to how to proceed.

The next major topics discussed by the Associate Administrator were the FY 2000 Operating Plan and the FY 2001 budget proposed by the President and now being considered by the Congress. Dr. Weiler noted that, while there had been a small net increase in the FY 2000 Operating Plan, significant adjustments had to be made in program content in order to accommodate the large number of earmarks ($78.5M worth) inserted by Congress into the FY 2000 OSS budget. These adjustments have adversely affected programs that have been openly competed and reviewed. For example, funds in the Research and Analysis (R&A) Program had to be reduced by 5 % across-the board in order to deal with the situation. Over the past several years, NASA has seen an enormous growth in earmarks and, if the trend continues, the consequences may be severe perhaps even entailing the cancellation of missions. There was considerable discussion of the fact that many of these earmarks were

directed towards science museums and a number of SScAC members inquired whether there might be a more organized approach for competitively dealing with the issue of funding science museums.

Dr. Weiler stated that the President's proposed budget for FY 2001 (and its associated runout) involved the biggest increase in the Space Science budget in history. He noted that the submission of the budget was just the first step in a political process in whose ultimate outcome would be decided by Congress. In spite of a projected $165 billion budget surplus, the budget spending caps are still in place. Impacts on domestic programs from remaining within the budget caps would be unacceptably severe, and both the Administration and Congress seem to be waiting for the other branch of Government to make the first move towards removing the caps in a presidential election year. Weiler noted that the political system finally seems to understand that there is a real coupling between the state of investments in science and technology and the state of the economy, so there should be some hope for increases in science and technology budgets this year.

Dr. Weiler reviewed the recent budget history for the space science program and discussed in some detail the significant new content contained in the President's budget. Highlights included the restoration of the New Millennium Program (OSS was rewarded for responding to OMB complaints), significant additions to the Mars Program (a decision made two weeks after the Mars Polar Lander failure), the addition of a new line for Discovery Micromissions, and the Living With A Star initiative. With respect to Living With A Star, Weiler noted that the scientific community had finally succeeded in developing a coherent story about SEC science. NASA is undertaking this Initiative for purely scientific reasons, but there are many potential applications from the new science that should benefit other agencies with more operational interests.

Dr. Weiler indicated some of these increases came with clear guidance from OMB concerning program content or direction. For example, the new line for Astrobiology Instrument Technology came with specific guidance that the funds were not to be used for building a building or outfitting a laboratory. The need for such a facility was yet to be demonstrated. OMB's interest in Mars was centered on the idea of developing a long-term sustained presence on Mars and not on a rush to return a sample by an arbitrarily posed date. Such a sustained presence will probably involve improved capability on Mars for communications and navigation, better surveys of the surface, detailed reconnaissance of potential landing sites, etc. He said that science will drive the architecture for the Mars Program and that the basic question still remains the search for past or current life. A robust approach is needed which will do many more things than just bring some rocks back. Sample return is likely to be a major part of the new architecture but will not drive the whole program. He stressed that OSS's first priority is to replan the Mars Program to produce the highest possible chance of meeting the scientific objectives within the available budget. OSS has not imposed any particular set of technical or schedule constraints on the replanning efforts.

There were a number of Committee comments concerning the need to make a better case for the importance of the R&A program. Dr. Weiler stated that, independent of the realities of the situation--there have been significant changes in the detailed content of many parts of the R&A program over the years--the R&A program was not generally viewed as a vibrant, dynamic program capable of responding to new scientific needs. Arguments regarding the need for providing broad support to the scientific community have not worked. Budget levels for many elements of R & A were set more than 20 years ago and have not changed much since, and there is no reason why past history should be determining the content of the current program. There was agreement that these are complex issues requiring further discussion. There is a need to make a stronger case concerning the importance of R&A to the total OSS program and to have mechanisms to rebalance the program where

needed. These issues were discussed further with Guenter Riegler during his presentation on the Research Program.

Dr. Weiler concluded his presentation by noting that, if Congress approves the Living With A Star Initiative, all the OSS Themes except for SEU would be in excellent shape. A new SEU Initiative is now being put together for consideration in the FY 2002 budget process.

Chairman Squyres congratulated the Associate Administrator for the good news on the budget. Specific program and budget issues raised by Dr. Weiler's presentation were considered by SScAC later in the meeting as part of the formulation of Committee recommendations.

OSS Strategic Plan/Discussion

Dr. Marc Allen noted that draft copies of the OSS Strategic Plan had been distributed to all Committee members in advance of the meeting. The purpose of this discussion was not to do a detailed editorial review of the text but to obtain broad reactions to the overall approach, structure, and tone of the Plan. Following brief remarks by Dr. Allen concerning the rationale behind the ordering and content of certain key sections of the Plan, the following major points emerged in the subsequent discussion of the Plan by the Committee:

- The section dealing with the Research and Analysis program is weak and needs to be strengthened significantly. The earlier discussion at this meeting concerning the R&A program illustrates the need for a stronger write-up.

- The text needs to be reviewed to see how successfully Technology, Astrobiology, and Education/Public Outreach have been embedded into the fabric of the Plan. It appears that a reasonable job has been done with Technology, but Astrobiology does not come across as an integrating theme, and Education/Outreach still seems to be treated as an add-on. Additional work needs to be done in both these areas.

- Considerable unease was expressed by some members concerning the focus on Human Spaceflight and its relationship to the future of Space Science that appears in the concluding section of the Plan. SScAC has never explicitly addressed this issue and it is not clear that the Committee shares the views expressed in this Section. The desirability and appropriateness of this emphasis (particularly as the concluding section of the Plan) might be reexamined.

Dr. Allen noted that in order to meet the schedule for completion of the Plan, he needed feedback from Committee members by the first of May in order to rewrite in May and distribute a new version in June for discussion at the summer meeting. Members were asked to respond to Dr. Allen directly.

Dr. Squyres offered the Committee's thanks to Marc Allen for all his work on the Strategic Plan. The Committee looks forward to seeing the next version of the Plan and to discussing it at the next meeting.

Solar System Exploration Theme Report

Dr. Carl Pilcher reported on recent results from several solar system exploration missions. He showed pictures from the NEAR mission now in orbit around the asteroid Eros saying that the images showed evidence for the existence of a variety of geologic processes affecting the surface. There is clear evidence for resurfacing (e.g., the existence of a smooth section overlying a heavily cratered surface) raising the basic question as to what kind of processes could have altered the surface of an asteroid. Dr. Pilcher showed recent results from the laser altimeter on Mars Global Sur-

veyor that reveal a large, very smooth area in the northern hemisphere of the planet that seems to have been created early in its history. Combined with other arguments for the early presence of appreciable amounts of water, these observations suggest the possible presence of a transient ocean in the northern hemisphere. Finally, Dr. Pilcher discussed a recent analysis of the cycloidal fractures on Europa. The analysis suggests that the cracking is produced by stresses in the ice generated by varying tidal forces acting on the satellite in its eccentric orbit. If the theory of how the cracks were formed is correct, it may provide valuable information on the thickness of the ice crust—information that may indicate whether it would be possible to penetrate through the crust to reach a subsurface ocean.

Sun-Earth Connection Theme Report

Dr. George Withbroe focused his report on an overview of the Living With A Star Initiative. He began by reminding the Committee of the connections between the behavior of the Sun and practical concerns. He described the Space Weather Research Network and other elements of the Initiative. The plan is to start launching new spacecraft in 2006 in order to have a full capability in place by the next solar maximum and then operate the resulting fleet of spacecraft through a full solar cycle. Discussions have already been held with a large number of other Federal agencies concerning their interest in participating in the program, and exploratory discussions are beginning with potential international partners as well.

In response to questions, Dr. Withbroe indicated that the Initiative would be part of the National Space Weather Program and that it is being structured as a self-contained NASA research program. However, other agencies can benefit from participating. The issue was raised as to whether the Initiative might be viewed politically as an operational program and hence not NASA's business. Withbroe reiterated that Living With A Star is a basic research program but that the data it produces might be operationally useful later on after the Solar Cycle is better understood. It was pointed out that this situation has ample precedents--data collected from other research satellites such as SOHO and Yohkoh are already being routinely used for operational purposes. From discussions held to date, there is no sense that other agencies feel threatened by this Initiative. There is a great deal of interest, and it is being treated as a good opportunity by everyone.

Astronomical Search for Origins Theme Report

Dr. Anne Kinney opened her presentation by expressing her thanks to Dr. David Black, the outgoing Origins Subcommittee Chair, for all his valuable service to SScAC and the community. Alan Dressler will be replacing him as Subcommittee Chair, and she was looking forward to working with him. Highlights reported by Dr. Kinney during her discussion of program status included:

- The successful repair of the Hubble Space Telescope (HST). It was a great way to end the year.
- Release of the Next Generation Space Telescope (NGST) NASA Research Announcement (NRA) for Phase A/B technology development.
- Release of the SIM Announcement of Opportunity (AO) soliciting the early observing programs and membership on the SIM Science Team. It was noted that for technical reasons the SIM schedule was likely to slip by a year.

- Proposals from industry for TPF studies are now in and reviews of the proposals are now underway. Selection of contractors will take place this spring.

Dr. Kinney also noted that the KECK Outrigger development was proving to be slower and more expensive than had been anticipated and that significant problems had been encountered in receiving approval for the site development.

Kinney then discussed the strategic structure of the sequence of "Origins" observatories and how the missions were related to each other. The overall direction of the program is to address, at each stage, the technology required for the next generation of observatories.

Report from the Planetary Protection Task Force

Dr. Squyres introduced this discussion by stating that the focus of much of the Solar System Exploration program on sample returns from a variety of bodies made the planetary protection issue an extremely important one and that the recommendations of the Task Force needed to be considered very carefully.

Dr. Norine Noonan, the Task Force Chair, began by reviewing the membership and mandate of the Task Force. She commented that the Task Force had very broad membership and was well suited to address the issues it had been asked to address. The group had held two meetings and completed its work in the fall. Dr. Squyres noted that, because of the Galveston Workshop, this meeting was the first opportunity for SScAC to review the Task Force's findings.

Two of the three findings presented by the Task Force—those dealing with the adequacy of the guidelines and protocols established for planetary protection for future Mars missions and their consistency with the advice of the Space Studies Board, and with the level of planetary protection requirements needed for the MUSES-C mission—were endorsed by SScAC as presented. With respect to the Mars missions, it was noted that the SSB guidelines represented a good starting point but that the planetary protection issues associated with Mars exploration and a Mars Sample Return would have to be considered in much more detail by a subsequent Advisory Committee.

The balance of the discussion was devoted to the recommendation dealing with the formation of a Planetary Protection Advisory Committee (PPAC) and the independence and level of reporting for such a committee. Dr. Noonan stated that the Task Force felt very strongly that there was a need for an independent advisory committee and that, because of the likely public visibility of the issues to be dealt with, this committee needed to report at the level of the NASA Advisory Council itself. She stated that it should be a standing committee parallel to SScAC reporting directly to the Associate Administrator for Space Science, the NASA official charged with Agency responsibility for planetary protection. In the view of the Task Force, establishing and maintaining the independence and credibility of the committee were paramount issues and required the establishment of a very high level committee. Time is also of the essence because there are major issues that need to be dealt with by such a group as soon as possible.

A number of key points were raised in the subsequent discussion. Chairman Squyres and others said that the Charter for the PPAC needed to contain a very clear definition of the term "Planetary Protection" and a clear statement bounding the scope of responsibilities of the committee. The focus should be on the policy issues associated with protecting Earth from organisms originating elsewhere and protecting other bodies from organisms originating on the Earth. This committee should not address issues that are purely scientific in nature.

It was noted that the membership of this committee would have to be very different from that on the usual NASA committees. For example, there are critical issues associated with risk and risk communications that will need to be addressed. The recent public debate concerning the safety of genetically modified foods should serve as a warning as to what might happen if such issues are not properly handled. There was considerable discussion concerning the role of international organizations on such a committee, particularly since more and more countries are developing the capability to bring back samples or to participate in a significant way in sample return missions. Noonan said that a true international committee is likely to be operationally unwieldy and would lack enforcement authority. For that, international treaties are necessary. It should be noted that the 1967 SpaceTreaty contains no provisions for enforcement.

The Committee discussed the appropriate level of reporting for the PPAC at some length. Some thought the committee should start as an SScAC subcommittee and that its reporting level could be raised later, if needed. Others felt that reporting through SScAC would represent a conflict-of-interest, would undermine the credibility of the committee, and that a separate NAC committee was needed. Dr. Noonan said that there would inevitably be controversy about the issue of planetary protection and that it was better to establish a committee at a high enough level that it would have the credibility to keep the debate inside the NASA community rather than outside. She said it was a case of "pay me now or pay me later"-- arguments which could be resolved inside NASA or in some other more public forum. Others pointed out that NASA itself needed to take a very proactive approach in framing the issues and engaging the public. Planetary protection issues are not perceived by the public as just science issues and, if NASA does not deal with them in a credible fashion, someone else who may be less friendly to the science will be given the job.

At this point in the meeting, it was clear that the Committee had not reached a consensus on this issue. Dr. Squyres expressed the view that there were going to be times where the needs for planetary protection and the needs for doing planetary science were going to come into conflict. Because of this, he was uneasy about having PPAC report in through SScAC. The subject was discussed further later in the meeting and the final recommendation from SScAC are contained in Appendix E.

Structure and Evolution of the Universe Subcommittee (SEUS) Report

Dr. Bruce Margon, Chair of SEUS, noted that his presentation would include the report on the state of the Theme that normally would have been given by the Theme Director. He began by showing some results from the Chandra X-ray observatory. He said that Chandra was doing very well and new results are emerging from almost every pointing. For example, x-ray emission has now been detected from stars in all stages of stellar evolution. The European XMM mission was successfully launched on an Ariane 5 on September 10. There is substantial U.S. participation in this mission. With the launch of this mission, x-ray astronomy has now entered the age of spectroscopy. Early results have shown, for example, the existence of new processes in stellar chromospheres and coronae.

The next major advance in x-ray spectroscopy (use of an x-ray calorimeter) was to have been carried aboard the Astro-E mission, which was lost in a launch vehicle failure. Dr. Margon said that it was essential to recover this capability, but it was not yet clear how, or how soon, that could be done. Constellation-X is the next obvious opportunity, but that mission is still not approved for development. Margon repeated Dr. Weiler's message that a decision to deorbit the Compton Gamma Ray is a public safety decision not a science decision. Fortunately, a number of other gamma-ray astronomy missions are on the horizon and the field retains a bright future. In particular, SWIFT has

been selected as one of the new MIDEX missions and is scheduled for a 2003 launch. It will study the after-glows of gamma-ray bursts. The primary science investigation for GLAST has also been selected. Stanford University will lead this investigation with the Department of Energy as a significant participant.

Looking towards the longer-term future, Dr. Margon said that Constellation-X is even more important in the wake of the loss of Astro-E. The mission is making reasonable progress given the limitations on technology funding. He compared the space-borne LISA mission and the ground-based gravity wave interferometer LIGO. He noted that LISA would detect the lower-frequency, gravity waves that were likely to be emitted by a wide variety of astrophysical sources. The mission is technologically very challenging and flight demonstrations of key technologies will be needed before a full commitment is made to proceed to development. There is substantial interest in Europe in participating in this mission

Finally, Dr. Margon said that "Cosmic Journeys" approach to packaging SEU science was received well by Mr. Goldin. The Theme now has both projects of high scientific merit and a coherent way of presenting them. The next step is to sell it to OMB and Congress.

Sun-Earth Connection Subcommittee (SECAS) Report

Dr. Andrew Christensen, chair of SECAS, began his report by stating that the fact that the Living With A Star Initiative is now in the budget is a major advance. The challenge is to make sure that it becomes real.

One major issue identified by SECAS during its last meeting (in the midst of a major snowstorm) concerned the impact of possible delays in the Europa Orbiter launch on the Solar Probe schedule. He reminded the Committee that the 2007 launch date for Solar Probe had been carefully selected in order to permit measurements to be made at key times in the solar cycle. Dr. Squyres reminded everyone that SECAS and SSES had worked hard together to establish an Outer Planets launch sequence and launch dates. SScAC is already on record concerning the criticality of maintaining the Solar Probe launch date. That position will be reiterated

SECAS was also concerned about the spate of recent mission failures. If care is not taken, a risk-averse culture will develop which will result in the imposition of more reviews without any relief on cost caps thereby increasing the pressure on everyone in the system. Dr. Christensen stated that NASA needed to clarify /quantify what is meant by an acceptable level risk and address the cost implications of lowering the risks for lower cost missions. Several SScAC members noted that this was a critical issue but that insufficient information was available to address it properly at this meeting. The results from the Young Committee and the implications of those results for the rest of the OSS program also need to be understood and discussed in some depth at a future meeting.

Finally, SECAS supported the restructuring of the R & A program into Clusters and endorsed the management approach of pairing civil servants and IPA's within Clusters in order to provide both a broader view and greater continuity of management. It was pointed out that the Cross-Theme Theory and Data Analysis Cluster covered a broad range of science, and SECAS was concerned about the difficulties in achieving appropriate balance within such a broad Cluster.

Astronomical Search for Origins Subcommittee (OS) Report

Subcommittee Chair Dr. David Black reviewed the results of the Subcommittee meeting held at the Ames Research Center in mid-February. Principal topics addressed at that meeting were Astrobiology, HST, SOFIA, and the R & A program.

With respect to the R & A program, Dr. Black noted the difficulties associated with recruiting capable people to come to Headquarters to work as Discipline Scientists. He stated that Headquarters needs help in recruiting and that SScAC and its Subcommittees needed to play an active role in providing such help. He also indicated that the Subcommittee had endorsed the restructuring of the R & A program and the cluster concept.

With respect to SOFIA, recent performance analyses suggest that the "seeing" may be four times worse than the Level I Specification (0.2 arc seconds RMS), and the Project Office is now assessing the scientific impact of the degraded performance. The situation is still unfolding and will be watched closely.

Dr. Black noted that the HST program has had to absorb $69 million in costs associated with the extra refurbishing mission and other requirements. So far, the extra funds have been accommodated within the Project budget over the next 4 years. This has been done by reducing support for the Guest Observer (GO's), Guaranteed Time Observer (GTO's), and Hubble Fellows Program by 8% which is near the upper limit of what OS had previously said were acceptable levels of reduction in order to accommodate problems. However, the Subcommittee does not believe that HST has seen the full impact of the costs associated with Space Operations Management Office (SOMO), and the Project is rapidly running out of maneuvering room. Again, the situation will be watched very carefully.

Much of the OS meeting was spent on Astrobiology, and Dr. Black reported that the NASA Astrobiology Institute (NAI) appears to be on track but that it is still much too early to judge success or failure. The Subcommittee felt that, after the upcoming round of selections of new members for the NAI, adding additional new members should have a lower priority than making sure that the existing members are adequately supported. Funding levels proposed by current members were substantially cut back, and it is more important to have a fair test of the concept with a viable set of current members than to continually expand the membership.

With respect to the proposed Astrobiology Laboratory, a subject which has concerned SScAC since it was first raised a year ago, Dr. Black stated that the Ames Research Center has continued to put a great deal of effort into identifying the needs for and prospective uses of such a facility. Workshops have been held, and an independent science team has been convened to assess candidate uses. However, it is still the OS position that, so far, no clear and strong astrobiology-oriented scientific imperative for such a facility has emerged. Dr. Black pointed out that, even if NASA doesn't actually pay for the construction of the building, the existence of the facility could represent a very substantial lien on NASA for instrumentation and maintenance.

Finally, Dr. Black said that Astrobiology is a subject that is likely to have a very important role to play in OSS's and NASA's future. It crosses traditional disciplines within OSS and includes significant components of the Code U and Code Y programs as well. There are significant issues associated with the organization and management of such a broad program. In order to address such issues, the Origins Subcommittee strongly recommends establishment of an SScAC-level Task Force to review the Astrobiology program, assess approaches to organization and management, and help

ensure that this important new field is established on a firm foundation. The proposal for establishing such a Task Force was discussed later in the meeting.

Solar System Exploration Subcommittee Report

New Subcommittee Chair Dr. Michael Drake summarized the discussions that took place at the most recent SSES meeting. One particularly critical issue that was considered concerned the ordering of the launches of the Europa Orbiter (EO) and Pluto-Kuiper (P-K) Express missions. Technical issues are now emerging that may require changes in the launch sequence. In the current baseline program, the Europa Orbiter is to be launched in 2003 with arrival at Europa in 2006; P-K is to be launched in 2004 with a Pluto flyby in 2014. However, a P-K launch in 2003 would be more energetically favorable, permitting a larger payload to be carried while still retaining the 10-year trip time. P-K also needs to launch in either 2003 or 2004 in order to be able to use a Jupiter gravity assist. Any later launch date would require a direct flight. The timing of the Pluto launch is also likely to depend on the availability of a suitable power source. There is a complex mix of issues at play here, and neither a formal recommendation nor a decision has been made regarding making changes in launch dates. However, SScAC needs to be aware of the issues. Dr. Squyres reminded everyone of the earlier discussion and the Committee position regarding maintaining the Solar Probe launch date in 2007. SSES missions should solve their problems within the Theme. If the Europa launch date slips further, it should not impact the launch of Solar Probe.

Following an extensive discussion of the scientific logic and requirements underlying any comprehensive program of Mars, Dr. Drake concluded his presentation by raising several issues that he believed needed further consideration. The issue of extended missions received particular consideration. As things now stand, a choice often has to be made between extending an operating mission and initiating a new program. He said that it was never smart to turn a productive asset off and warned that Cassini would be facing this problem some day. A Cassini extended mission would probably cost $30-40 million per year, a significant fraction of the current Outer Planets line. Where would the necessary funds come from? Dr. Pilcher noted that the planetary program did not have a pool of money available to extend missions. Dr. Black pointed out that the Senior Review Process was intended to be able to deal with these issues, although, up to now, the planetary community has not had to explicitly deal with making such trades. Dr. Drake concluded his remarks by stating that the Committee needed to get across the idea that R&A is really part of a great cycle of science that includes the original mission, then DA, then R&A, and then the formulation of new questions that result in new missions. The critical role of R&A in this whole process needs to be better articulated.

Wednesday, March 1:

Report from the Technology Readiness Task Force

Dr. Squyres introduced the meeting by noting that the key subjects for consideration today were technology and Astrobiology. SScAC also needed to return to the subject of the Planetary Protection Advisory Committee to see whether a consensus position could be developed.

Dr. Daniel Hastings reported on the findings of the Technology Readiness Task Force, which had been asked to determine how well NASA technology investments support the Space Science Strategic Plan. He reminded the Committee of the membership of the Task Force and said that they had met in two sessions to consider four basic questions:

- Have missions and visions been articulated sufficiently to drive technology objectives and capabilities?
- Have technology objectives and capabilities been appropriately described for missions and visions?
- Have technology objectives and capabilities been well integrated across the four science themes into a single set of technology developments?
- Is the technology development currently planned in the various program elements appropriately scoped, scheduled, and funded to satisfy the strategic missions and visions of the Space Science Enterprise?

Dr. Hastings said that the Task Force found that, overall, technology programs were appropriate, valuable, and necessary. A lot of good work is currently going on. However, the Task Force also found that:

- Technology work was substantially underfunded in some cases with the degree of underfunding differing substantially among themes;

- The Agency structure for planning and managing technology is unclear and complex -- Byzantine was the best one word summary they could find to describe the situation;

- More emphasis needed to be placed on developing a strategic supporting infrastructure (e.g. better communications at planetary distances) for space science missions rather than having every mission develop its own infrastructure; and

- Knowledge of what other agencies were doing in technology was sporadic.

Further details concerning Task Force findings (including a Theme-by-Theme analysis of technology readiness) may be found in Dr. Squyres' findings and recommendation letter (Appendix E).

With regard to the issue of coordination of technology programs with other agencies, Dr. Hastings observed that a change in management culture in NASA is required. Partnering is imperative in order to take maximum advantage of limited resources. The NASA Administrator frequently talks about the need for partnerships, but this message does not seem to have penetrated sufficiently to lower levels of the NASA organization.

In the general discussion of the Task Force Report, Dr. Squyres stated that he had been particularly struck by the fact that the Task Force had come to such different conclusions for each Theme. These differences suggested that broad technology issues are not being examined in a systematic way—a much more fundamental problem for OSS. He and other SScAC members also observed that the Task Force needed to come up with more specific recommendations to accompany their findings--an observation that was considered at more length in the subsequent discussion with Dr. Ulrich. The findings need to be turned into a clear set of recommendations that OSS can act upon. Drs. Anderson and Hastings were asked to develop a process for accomplishing this and to report on the Task Force recommendations at the next meeting of SScAC.

Technology Program Report – Responding to the Technology Readiness Task Force

Dr. Peter Ulrich, Director of the Advanced Technology and Mission Studies Division, reported on steps that had been taken to date to respond to the Task Force's findings. He said that the Task Force's critique was fair and constructive and had acted as a driver and a motivator to seriously address the issue of the integration of technology development. He said that integration efforts had been institutionalized through creation of a Technology Steering Committee. The near-term objectives of this Steering Committee are to focus on strategic plan missions, organize a compilation of technology requirements and current development plans, analyze the adequacy of those development plans, identify optimization approaches, formulate augmentation justifications where needed, and monitor and report on general program progress and problems.

With respect to the issue of adequacy of funding for technology development for different Themes, Dr. Ulrich noted that shortfalls in technology funding for Sun-Earth Connection should be taken care of as part of the Living With A Star Initiative. He noted the Task Force finding concerning the apparent fragmentation of the Solar System Exploration efforts, and stated that it was clear that a more programmatic approach needed to be taken. Achieving this will be one of the goals of the Technology Steering Committee.

In the general discussion on his presentation, Ulrich was urged to treat issues that involved tradeoffs between meeting needs for technology and satisfying science requirements very carefully. Sometimes it is possible to adjust science requirements slightly in order to meet science goals and not drive the technology too far. At other times, the science requirements are legitimate and must be met. It is important to get regular feedback from the users of technology throughout the process.

Dr. Squyres stated that it was clear that Dr. Ulrich and his staff had already started to address the issues raised by the Task Force Report. The Report is rich in findings but, as noted earlier, it needs to go further and present specific recommendations. It was agreed by the Committee that, at this point, more fact finding would probably not be useful. The reality of the situation is that the technology program is still somewhat amorphous, and the Task Force has identified a number of critical shortcomings and weak spots. Dr. Squyres suggested that SScAC accept the Task Force findings and reiterated the request that the Task Force turn those findings into a clear set of recommendations, which will be considered at the next SScAC meeting. If any of the findings need to be adjusted in light of the real Strategic Plan, that issue should also be addressed by the Task Force in completing its work.

Research Program Report

Dr. Guenter Riegler began his report by bringing the Committee up-to-date concerning recent SOMO activities. He noted that a representative set of users have now been invited to participate in the annual performance evaluation of the Consolidated Space Operations Contract (CSOC). This users group reports to SOMO itself. CSOC has also set up an external science advisory group and a number of space scientists are on that group. Dr. Riegler indicated that he had reviewed the membership of the Advisory Committee, and he was satisfied that it was a reasonable group. A number of SScAC members felt that it would be useful to know the membership of both groups, and Dr. Riegler said that he would try to supply this information. He said that the necessary support for providing basic SOMO services for FY 2000--2002 had been identified. So far, OSS has not been adversely affected. However, there are still out-year issues that have not been fully addressed. Announcement of Opportunities (AO's) still allow freedom of choice as to whether to propose use of

CSOC services or not for a PI-class mission. Following selection of a proposal, a cost comparison is being done as a basis for a making a final decision as to whether to require the use of CSOC. To date, the process seems to have resulted in reasonable outcomes. SOMO has been very accommodating and has managed to lower its costs to live within the available funding. Code M funding has been available to resolve problems without penalizing OSS. If SOMO costs were to increase, handling such increases will be treated as an Agency-wide budget issue, not a Code S problem.

In response to a question concerning the oversubscription of the Deep Space Network (DSN), Dr. Riegler noted that this has been an issue for a long time and that the issue predates SOMO. Various solutions are being examined including having the DSN go to Ka band to increase capacity. Right now, the oversubscription problem seems to be manageable, at least in the near term. Dr. Squyres stated that this issue needed to be examined in detail by the SSES. This is a problem that will ultimately have to be solved at the Code S Level, and input from the Subcommittee is needed.

Dr. Riegler went on to describe staff changes in his Division. He said that a number of positive changes were now underway. Key Intergovernmental Personnel Agreement (IPA's) employees finishing their terms have been replaced. Selections for Senior Scientists for Astrobiology, Planetary Protection, and Space Science Research should be announced shortly. Applications for the Mars Exploration Program Scientist are being reviewed now. The cap on the number of visiting scientists on IPA appointments will be raised, and the Division will focus on recruiting people in areas where specialized expertise is needed to support new programs. Help will be needed in finding such people.

Dr. Riegler then described the Research Opportunities in Space Science (ROSS) 2000 NRA, noting that it had been restructured around the Cluster concept described (and endorsed) at previous SScAC meetings. The intent of this whole approach is to address issues raised by the Black Task Force. For this NRA, proposals within a Cluster will be reviewed as a group permitting tradeoffs to be made among disciplines within a Cluster. The Senior Review Process will start in FY 2001. This process will also be used to examine such questions as the appropriateness of the structure of each Cluster, the quality and productivity of work undertaken in each Cluster, whether the work is coupled to the Strategic Plan and supports priorities within that Plan, and whether funds should be reallocated across Clusters.

Dr. Riegler concluded his remarks by revisiting the earlier discussion concerning the importance of the R&A program. He said that it is critical to find ways to highlight more of the accomplishments of this program, and that the Division was exploring a variety of pathways for publicizing such results. Help from the community is needed to accomplish these objectives.

Committee discussion of this presentation was centered on the fact that SScAC was pleased with what they had heard. The restructuring of the R&A program is responsive to previous recommendations. The Committee expressed its appreciation to Dr. Riegler and his staff for all the hard work that they had done. A number of SScAC members observed that the Senior Review will need to have some very well-defined guidelines/metrics in order to arrive at judgements concerning the quality and impact of the work being done in the R&A program. Usual metrics, such as number of papers published, will not be adequate for this purpose. Dr. Riegler indicated that he expected to have a draft description of the Senior Review process by the fall. Dr. Squyres reemphasized the point that developing good metrics will be a key to this process. Preliminary ideas on such metrics should be discussed with SScAC at the next meeting.

Lunchtime Science Talk: Early Scientific Results from the Chandra Mission; Increased Cooperation with the Space Studies Board

Dr. Claude Canizares, Chair of the Space Studies Board, discussed two topics in his presentation. Most of the time was spent providing a comprehensive overview of the early results from the Chandra X-Ray Observatory. Both imaging and spectroscopic results from a wide variety of astrophysical objects were described, amply illustrating the power of the new capabilities provided by Chandra to address a broad range of fundamental problems in astronomy.

Dr. Squyres and Dr. Canizares jointly discussed possibilities for increased interaction between SScAC and the SSB. Both recognized that the two Committees play different roles but that, at times, the roles blur somewhat and there is a need for improved communications and coordination between the two groups. As a first step, observers from each Committee will be invited to attend meetings of the other group.

Astrobiology Program Report

Dr. Squyres introduced the next set of presentations by stating that the subject of Astrobiology has now become a major thrust for the Agency, and that SScAC has been interested in this area for some time. Now that an Astrobiology Institute Director is in place, this meeting was an opportune time to receive a broad overview of the program.

Dr. Michael Meyer began by stating that Astrobiology was concerned with answering three central questions:

- How does life begin and evolve?
- Does life exist elsewhere?
- What is the future of life on earth and beyond?

Based on these questions, over the last few years, a more detailed set of goals and objectives have been developed that are contained in the Astrobiology Roadmap discussed with SScAC last year.

Dr. Meyer noted that, at the present time, Astrobiology contains three main program elements: a grant program which supports work in exobiology and evolutionary biology; the NASA Astrobiology Institute (NAI); and a program in technology and instrument development. He pointed out that Code Y was providing some support for the Institute and that the NASA Life Sciences Division is also supporting work in evolutionary biology. The Ames Research Center (ARC) is acting as the lead Center for Astrobiology. In this capacity, they manage the NAI (all the Institute funds go through ARC), and have recently created an Astrobiology Integration Office. The goal of the technology and instrument work is to develop the capability to actually influence missions. The discipline wants to ensure that missions include appropriate instrumentation to address basic questions in Astrobiology, and such instruments need to be identified and developed. The OMB passback clearly reflected the importance of such work.

Recent activities in the discipline include collaboration with the National Science Foundation in the implementation of the Life in Extreme Environments Program; broad community participation in a variety of professional meetings (the fact that there were 26 special sessions on biogeosciences at the recent AGU meeting led the AGU to form a new Section in this field); and participating in re-

views by many committees. It is clear that there is increasing interest in the broader scientific community in Astrobiology.

With respect to the proposed Astrobiology Laboratory, Dr. Meyer reminded SScAC that the basic idea is to have a well-equipped facility that would be open for use by the entire scientific community. The critical point raised by several members of the Committee was that it was far from clear that the Astrobiology community had concluded that there is any need for such a facility. A compelling case has also not been made for locating it at ARC. These issues were discussed at length later in the meeting.

Astrobiology Institute Report

Dr. Baruch S. Blumberg, Director of the NAI, began his presentation by noting that the initial 11 teams were selected about a year ago, and so the Institute is still really in a start-up phase. All selected teams were consortia of institutions and none of the teams had received the full funding they requested in their proposals. There was a clear emphasis on cross-disciplinary activities from the beginning, and this emphasis is one of the unique aspects of the Institute. Dr. Blumberg noted the challenge associated with bringing together disciplines that approach doing their science in such very different ways.

Blumberg described the overall structure of the Institute and how it operated. He noted that he had established a Science Council to advise him. Members were selected for their breadth of expertise. He felt that achieving a broad perspective was important. The NAI itself involves 470 participants including 13 members of the National Academy. Dr. Blumberg stated that he felt it was important to give people the latitude to pursue the most promising directions for research. This approach is particularly important when you are trying to define a new field of research and experimenting with a new approach to conducting such research. A lot of new science is being done which probably wouldn't have been done if it were not for the Institute and its focus on cross-disciplinary work. Following a description of some of the main lines of research being pursued, Dr. Blumberg commented that the new Astrobiology CAN will be directed towards filling in critical gaps in research currently being pursued.

Dr. Blumberg then described some of the mechanisms that were being used to foster collaboration among the teams. Members were being encouraged to meet regularly in a variety of settings. A number of focus groups have been established to attempt to get people together based on their interest in particular projects. A number of electronic collaborations have been established. While video conferencing is being used regularly and is proving to be effective, Dr. Blumberg also felt that there really is no substitute for people being able to get together on a regular basis.

At the end of the presentation, a number of SScAC members commented that they felt that they had a much better understanding of what NAI was and what it was trying to do. Committee members were pleased with what they had heard. Astrobiology is an exploding field. The Institute is putting a broad intellectual framework in place and is doing exactly what needs to be done to invent a new field. Because the field is new, there are still many open issues, and things may still look somewhat amorphous; but this situation is exactly what is to be expected when something this new is created. Dr. Blumberg commented that the key to the whole approach was to competitively select the best science. Taking such a bottoms-up approach has been exactly the right way to proceed.

Discussion of Astrobiology Efforts

Most of the subsequent discussion concerned the proposed Astrobiology Laboratory. Strong concerns were expressed that it is premature to make a decision to invest significant resources in a laboratory whose rationale for existence is still far from clear. Members felt that it was also not clear that, even if such a facility were needed, there is a strong case to be made for locating it at the Ames Research Center. Is it better, for example, to establish a large facility at Ames rather than creating a more distributed capability at universities across the country? If the concept of a distributed institute whose members are electronically linked turns out to be viable, it would be hard to make a case for a need to co-locate significant concentrations of people and instruments at a single location. In fact, this was the rationale (endorsed by SScAC) for the establishment of NAI as a "virtual institute" in the first place. In any case, the need for facilities ought to be considered independently of a decision regarding a particular site. Members also felt that competition ought to be the basis for a decision on the location of any facility whether it was a single large facility or a more distributed capability. Open competition and peer review need to be central elements of proceeding no matter how the issue turns out.

Dr. Black reminded the Committee that there is an independent science team now taking a critical look at the potential uses of a centralized Laboratory. SScAC needs to hear from this group before arriving at any final conclusions concerning the need for a Laboratory. There was general agreement that the Committee should have a briefing on the results of this study at the next meeting. Dr. Squyres pointed out that there is an important difference between seeing whether you could effectively utilize such a Laboratory if you had it and asking the question whether having such a Laboratory is the best way to develop key capabilities. Others raised the issue of the relative importance of a facility compared to the needs of the rest of the Astrobiology program. These broader perspectives must also be kept in mind. The issue of how to best acquire a facility is a separate one from these more fundamental concerns.

Chairman Squyres stated that the issue of how to put the proposed Laboratory into the broader context of identifying and addressing the needs for advancing the field of Astrobiology as a whole was a perfect introduction to a consideration of the proposed Astrobiology Task Force introduced by Dr. Black during his Subcommittee presentation.

Proposal for an Astrobiology Task Force

Dr. Anne Kinney reviewed the proposed charter for an Astrobiology Task. She stated that there is a need to obtain a good overview of the program by a knowledgeable outside group, and there are many critical issues to be addressed in order to develop a long-term plan for this emerging field. Dr. Kinney stated that a new group needed to be created because the expertise required to undertake a critical examination of the Astrobiology program goes well beyond the expertise available on the Origins Subcommittee. Task Force members will be selected to have the necessary breadth of expertise. Dr. Squyres noted that such a group will be able to put the Laboratory issue, which has been a source of considerable contention for some time, into the broader context of the needs of the field as a whole.

After some discussion, SScAC agreed that there was a need for such a Task Force and approved the establishment of such a group in principle. However, key details remain to be worked out concerning both the Task Force Charter and membership. Dr. Squyres reiterated that the intention was to establish a group with a finite lifetime. The intention is not to proliferate standing SScAC sub-

committees. A number of members were concerned about the proposed membership presented by Dr. Kinney which seemed to be more of an advocacy group than a genuine review committee. Dr. Squyres stated that SScAC will be a part of the process of establishing the membership of the Task Force and will have final approval of that membership. SScAC will work with Dr. Kinney to finalize both the Task Force charter and the membership.

Committee Discussion/Preparation of Recommendations

Most of the subsequent Committee time was spent considering the issue of the Planetary Protection Advisory Committee. Dr. Squyres reviewed the previous day's discussion noting that there was general agreement on the need for such a group but considerable disagreement as to whether it should report at the NAC level or through SScAC. Dr. Squyres reported that he had discussed this issue with Dr. Weiler who felt that reporting in at the same level as SScAC would give the group the necessary credibility. Dr. Weiler also felt that the Planetary Protection Task Force should focus on policy issues and that scientific advice should only come from SScAC.

The Committee accepted this guidance, but continued to be concerned as to whether scientific and policy issues were really separable. No matter how much care is taken in defining responsibilities and writing Committee Charters, the two sets of issues will inevitably become intertwined, and there needs to be excellent communication and strong linkages between the PPAC and SScAC.

Following another round of discussion during which most of the issues raised on Tuesday were revisited, the Chair polled the membership and found that there were still two firm sets of opinions regarding the issue of the reporting level. The majority view favored a NAC-level Committee but there was significant dissent from this position. Dr. Squyres said that both sets of views would be conveyed to Dr. Weiler and the NAC.

Thursday, March 2:

The Committee spent most of the morning preparing and discussing proposed findings and recommendations. The final results of those deliberations are contained in the letter from Dr. Squyres to Dr. Weiler in Appendix E. At the end of the morning, Dr. Weiler joined the Committee for an informal discussion of the issues raised at this meeting.

Report to the Associate Administrator

Chairman Squyres summarized the key points that had been considered at this meeting. He reported that the Committee was delighted with the President's budget proposal and was particularly pleased to see the inclusion of the Living With a Star Initiative. The budget represented a significant step towards achieving a strong program across all of OSS. The Committee also recognized that the budget submission represented only the first step in a long process.

Dr. Squyres reported the Committee position regarding the importance of maintaining the 2007 launch date for Solar Probe independent of decisions regarding the sequence and schedule for the Europa Orbiter and Pluto-Kuiper Express launches. He reported that the Committee was pleased with Guenter Riegler's presentation and that it appeared that real progress was being made in dealing with SOMO/CSOC. The Research Cluster concept is directly responsive to the recommendations of the Black Task Force. Fully implementing it will be a challenging job, but a good start has been made, and the approach is headed in the right direction. With respect to the Astrobiology Institute, Dr. Squyres stated that the Committee was very impressed with Dr. Blumberg's invigorating presen-

tation describing an innovative program of cross-disciplinary research. SScAC recognized that the Institute's work is really just getting started but the start is very promising. However, the "virtual" aspects of the Institute have yet to be realized.

SScAC is still concerned about the issue of the proposed Astrobiology Laboratory—an issue that generated much discussion at this meeting. The need for such a large central facility is far from clear and the Committee looks forward to hearing more from the science working group that is now examining the concept in more detail. Dr. Weiler noted that Mr. Goldin had asked him to specifically address the issue of the need for such a Laboratory. He added that new funds would not be available for equipping a laboratory, and finding the necessary funds for this purpose would require tradeoffs with adding new members to the Institute or addressing other critical needs in Astrobiology. Dr. Squyres stated that the SScAC Astrobiology Task Force whose establishment was approved at this meeting would be able to take a broad view of the needs of the field and provide the necessary scientific and programmatic advice.

Dr. Squyres reviewed the extensive Committee discussion of the proposed Planetary Protection Advisory Committee. While everyone agreed that there is a clear need for such a group, there were strong majority and minority views concerning the appropriate level of reporting. Dr. Squyres outlined the major issues underlying the division of opinion within SScAC. He noted that, whatever its reporting level, the focus of its activities should be on policy issues. However, there were going to be situations for which policy and scientific issues were going to become inextricably intertwined and, if a separate Committee were formed, there would have to be a close interaction between this Committee and SScAC.

Dr. Squyres reported that the Committee had considered the GP-B situation but was not ready to make any specific recommendations at this time. There was a sense, however, that whatever steps were taken should be based on maximizing the overall scientific return to OSS. If cancellation were required to avoid having an unacceptable impact on the rest of the OSS program, then the Committee would be willing to support such a decision. However, not enough information was at hand to come to a valid conclusion regarding this situation given the complexity of the issues. Dr. Weiler commented that this is a very difficult case. A lot of money has been spent on GP-B, and both Stanford and MSFC maintain that they know how to complete the program if the necessary funds are provided. However, the credibility of such statements is an issue. To be fair, Stanford has made enormous progress, and most technologies and systems have been successfully demonstrated, but a number of critical questions have yet to be answered. As was stated earlier in the meeting, Dr. Weiler was leaning towards delaying the decision and giving the project a chance to put things back together. If critical milestones are met, then he might arrive at one answer. If the outlook was for a continuing series of delays, then the answer is likely to be very different. The Committee agreed that the situation should be reviewed in detail at the next SScAC meeting.

Dr. Weiler concluded this portion of the meeting by commenting on issues being considered in conjunction with the restructuring of the Mars architecture. He noted that the previous architecture had a clear goal and a well laid-out sequence of missions and schedule. In retrospect, the program was very aggressive, technologically ambitious, and underfunded. Reserves were inadequate, critical aspects of the program (such as facilities for sample handling) were left out of the baseline program, and launch vehicle needs and costs were not adequately understood. Now that the architecture is being rethought, he will only be willing to commit to a program that has adequate reserves, identifies and budgets for all known needs, and is realistic enough to be actually doable. A program that meets these constraints might not make everyone happy. However, the Mars Program has just

gone through the equivalent of the Apollo fire, and the situation must be treated as an opportunity to come up with a fundamentally better program. Such a program must be resilient and must be capable of meeting the most important objectives (especially returning a sample) on its own. While international participation was welcome, he is not willing to allow an international partner to be on the critical path. International contributions complement and add to the baseline program but do not replace critical elements required for program success. Dr. Weiler commented that, while JPL had made a good start in redefining the architecture, many problems must still be solved. He will insist on taking the time to do the job right and will not allow the situation to be driven by artificial constraints. The new architecture must be very well thought out and must be based on a coherent, long-term view of where the program should be going. The Committee commented that such an approach is crucial for preserving NASA's and OSS's integrity and credibility. Dr. Weiler stated that, when HST had the problem with the primary mirror, the Agency told the truth about the situation no matter how painful this approach was. Confronting the reality of the situation was the right thing to do, and he expected to take the same approach towards redefining the Mars Program.

Final Words

Dr. Squyres closed the meeting by thanking the members leaving the Committee (Anderson, Black, DesMarais, Hastings, Urry, and Vondrak) for their service. The Committee was given a final opportunity to express concerns and bring up issues that should be considered at future meetings. In going around the room, concerns continued to be expressed about the technology program. A lot of money is being spent, but it is not clear that there is adequate coordination or a coherent process for establishing priorities to address the most important needs in support of the Strategic Plan. International technology transfer issues and the current approach to implementing International Traffic in Arms Regulations (ITAR) are becoming issues that should be discussed by SScAC. The conduct of international programs is being affected, and, if care is not taken, there will be unintended adverse consequences. The effect of congressional earmarks on the OSS budget and program is another subject requiring further consideration even though it is not immediately clear what can actually be done about this situation. Dr. Urry commented that, in her term on the Committee, she has participated in two strategic planning exercises and has seen a significant turnaround in OSS's budget prospects. SScAC has been effective, real progress has been made on a variety of fronts, and she has been proud to be part of the process.

The meeting was adjourned at Noon.

Appendix A: Agenda

Tuesday, February 29:

8:15 AM	Opening Remarks/Announcements	Squyres
8:30	OSS Program Status/FY 2001 Budget Proposal	Weiler
9:30	Discussion	
10:30	OSS Strategic Plan/Discussion	Allen/SScAC
Noon	Working Lunch	
1:00 PM	Theme Status Reports	
	Solar System Exploration	Pilcher
	Sun-Earth Connection	Withbroe
	Astronomical Search for Origins	Kinney
	Structure & Evolution of the Universe	Bunner
2:00	Report from the Planetary Protection Task Force	Noonan
2:45	Discussion	
3:15	Reports from Subcommittees	
	Solar System Exploration	Drake
	Sun-Earth Connection	Christensen
	Astronomical Search for Origins	Black
	Structure & Evolution of the Universe	Margon
5:15	General Discussion	
5:45	Adjourn	
6:30	Group Dinner	

Wednesday, March 1:

8:15 AM	Announcements	Squyres
8:30	Report from the Technology Readiness Task Force	Anderson/Hastings
9:15	Technology Program Report –	Ulrich
	Responding to the Technology Readiness Task Force	
10:00	Discussion/Technology Program Issues	
10:30	Research Program Report	Riegler
	ROSS 2000/Implementing the Cluster Concept	
	Science Review Process	
	SOMO Update	
11:15	Discussion	
11:45	Lunchtime Science Talk: Early Scientific Results from the Chandra Mission	Canizares
1:00 PM	Astrobiology Program	
	Overview	Meyer
	Astrobiology Institute	Blumberg
2:15	Discussion/Astrobiology Issues	
2:30	Proposal for an Astrobiology Task Force	Kinney
3:00	Discussion	
3:15	Committee Discussion/Preparation of Recommendations	
5:30	Adjourn	

Thursday, March 2:

8:15 AM	Announcements/Plans for Future Meetings	Squyres
8:30	Discussion/Preparation of Recommendations	
11:30	Report to the Associate Administrator	Squyres
12:15 PM	Adjourn	

Appendix B: Members of the Committee

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Appendix C: Attendees

Committee Members:

David Black	LPI
Andrew Christensen	Aerospace Corp.
David DesMarais	NASA/ARC
Michael J. Drake	U. of Arizona
Daniel Hastings	MIT
Isabel Hawkins	UC/Berkeley
Edward Kolb	FNAL
Molly Macauley	RFF
Bruce Margon	University of Washington
Richard Mewaldt	Caltech
James Papike	UNM
Jeffrey Rosendhal	NASA HQ/Code S
William S. Smith	AURA
Steven Squyres	Cornell
Meg Urry	AURA/STSCI
Richard Vondrak	NASA GSFC

NASA Staff:

Mark Allen	NASA/S
Bruce Betts	NASA HQ
Steve Brody	NASA HQ/Code SR
Bob Connorton	NASA GSFC
Kathy Dakon	NASA HQ/Code Z
D. DeVincenzi	NASA/ARC
Hashima Hassan	NASA HQ
Steve Holt	NASA/GSFC
Steve Horowitz	GSFC
Diana P. Hoyt	NASA HQ/Code Z
Scott Hubbard	NASA ARC
Anne Kinney	NASA HQ/Code Z
R. Netting	NASA HQ/Code S
Marian Norris	NASA HQ/Code S
Adrianna Ocampo	NASA HQ/Code SD
Carl Pilcher	NASA HQ/Code SA
Ronald Polidan	GSFC
John D. Rummel	NASA HQ/Code SR
Frank Six	MSFC, SD50
C. L. Sorrels	NASA HQ/Code S
Perry Stabekis	Lockheed/Martin/NASA HQ
Guy Stringfellow	NASA HQ/Code SR
G. Varsi	NASA HQ/JPL

Others:

Joe Alexander	NRC-SSB
Leo Andreoli	TRW
John Appleby	JHU/APL
Kirsten Armstrong	NRC-SSB
Kathleen Beres	TRW
Don Brennan	Orbital
Mark Burnham	Caltech
Don Burrowbridge	Orbital
Claude Canizares	MIT
Richard Capps	JPL
Bob Connely	SEU
Lamont DiBiasi	DiBiasi Associates
Tom Dickinson	NRC
Alan Dressler	Carnegie
Suzanne Frederick	JPL
Rob Fleming	Westover
Daniel Herman	Brashear LP
Paul Hertz	NRL
Luc Hon	UCB
Joanne Hopkins	SRI
Andrew Lawler	Science Magazine
Jon Malay	Ball
Jane Mellors	ESA
Norine E. Noonan	EPA
Richard Obermann	U.S. Congress
Bruce Tsurutani	JPL

Appendix D: List of Presentation Materials

1. NASA Space Science Status Report – Edward J. Weiler
2. Report to the NASA Office of Space Science by the Gravity Probe B Independent Review Team – Parker S. Stafford, Chair
3. NASA Space Science Enterprise – Presentation to Space Science Advisory Committee – Marc S. Allen
4. Sun-Earth Connections Subcommittee Report to SScAC—Andrew Christensen
5. Quest: To Chart Our Destiny in the Solar System—Michael Drake
6. Origins Subcommittee Report to the Space Science Advisory Committee – David C. Black
7. Structure and Evolution of the Universe—Bruce Margon
8. Report of the Planetary Protection Task Force of the Space Science Advisory Committee – Norine E. Noonan
9. NASA Technology Readiness in Space Science – Daniel Hastings and Christine Anderson
10. Technology Program Report – Responding to the Task Force on Technology Readiness – Peter Ulrich
11. Space Science Research – Presentation to the Space Science Advisory Committee (SScAC), Subcommittees, and Working Groups – Guenter Riegler
12. Space Studies Bulletin, Vol. 10, Issue 4 – Space Studies Board
13. List of reports and projects under consideration – Space Studies Board
14. Space Studies Board – Selected 1998 Reports
15. Space Studies Board – Selected 1999 Reports
16. Astrobiology—Michael Meyer
17. Astrobiology Oversight Task Force of SScAC Proposed Draft—Anne Kinney
18. NASA Astrobiology Institute – Baruch S. Blumberg

Appendix E: SScAC Findings and Recommendations

Cornell University
Center for Radiophysics and Space Research

December 2, 2002

Dr. Ed Weiler
Associate Administrator for Space Science
NASA Headquarters
Washington, DC 20546

Dear Ed:

The Space Science Advisory Committee (SScAC) met at NASA Headquarters on February 29 – March 2, 2000.

The highlight of the meeting was hearing from you about the President's FY'01 budget request for Space Science. We are delighted by the proposed increase in Space Science funding for the coming year, and throughout the next five years. The new budget wedge, which includes new initiatives for the Sun-Earth Connection theme, a flight technology validation program, a revised Mars architecture, and other programs, will help balance implementation of the Space Science Enterprise's Strategic Plan.

One of the most significant new programs in the budget is the proposed Living With a Star initiative. This initiative has the objective of developing the capability to observe, understand, and predict aspects of the Sun-Earth connection that affect life and society. We recognize the importance of understanding the mechanisms by which solar variability affects the geospace environment. We also recognize the potential societal benefits of developing a scientific basis for improved space weather predictions in an era when we have become increasingly dependent on space-based systems. ***We therefore encourage Code S to pursue aggressively the development and implementation of this important scientific research initiative.***

We also considered a number of other issues, and our findings and recommendations concerning them are summarized below:

Planetary Protection Task Force Report

One of the key events of our meeting was the briefing that we received from Noreen Noonan on the final findings and recommendations of SScAC's Planetary Protection Task Force (PPTF). We concur with their finding that ***the guidelines and protocols that have been established for planetary***

protection for future Mars missions are consistent with the advice of the Space Studies Board and represent a good starting point.

We also endorse the PPTF finding ***that the MUSES-C mission warrants no special containment or handling for samples returned from asteroid 1989ML.*** This recommendation may be revisited if additional relevant data become available. Consistent with Space Studies Board recommendations, these types of categorizations for other sample return targets should be handled on a case-by-case basis.

We concur with the PPTF recommendation that a Planetary Protection Advisory Committee (PPAC) be established by the NASA Administrator under the auspices of the NASA Advisory Council. A majority of the members of SScAC felt that, in order to maintain its independence and to minimize perceptions of conflict of interest, PPAC should report directly to the Associate Administrator for Space Science, the NASA official vested with Agency responsibility for planetary protection. However, we also recognize that planetary protection is inextricably linked to some scientific issues. For this reason, a significant minority of the committee felt that the PPAC should instead be a subcommittee of the SScAC. Regardless of the reporting path, ***we recommend that the charter of PPAC clearly delineate its charge to address only policy issues related to planetary protection, and to avoid issues that are purely scientific in nature.*** Specifically, their charter should restrict their purview to minimization of the inadvertent exchange of biological material between Earth and other bodies in the solar system, to a level commensurate with the potential of these bodies to sustain life or to harbor evidence of either prebiotic evolution or life.

PPAC members should be selected to ensure a balanced representation among industry, academia, and government with recognized knowledge and expertise in scientific, technological, and programmatic fields relevant to planetary protection, including astrobiology, planetary materials and environments, engineering risk analysis, risk management, risk communication, microbial ecology, biological containment science/technology, applicable law, and public health. In order to establish effective communication between the two committees, the SScAC chair or the chair's designee should be a member of the PPAC, and the PPAC chair or the chair's designee should be a member of the SScAC.

Technology Readiness Task Force Report

We also received a briefing from Dan Hastings describing the work of SScAC's Technology Readiness Task Force (TRTF). This task force has met twice, and has produced a detailed set of findings. **We endorse all of the TRTF's findings, and we pass them along to you in an attachment to this letter.**

While we believe that the attached findings paint an accurate picture of the current strengths and weaknesses of the Space Science Enterprise's technology program, the TRTF has not yet produced a detailed set of recommendations that are derived from its findings. Pete Ulrich has taken some first steps toward responding to the findings, but we feel it would be helpful to him if he had a clear set of task force recommendations that he could act upon. Accordingly, the TRTF has been asked to meet once more to generate their recommendations. The final report of the TRTF will be delivered at the next meeting of SScAC.

Astrobiology

Another major topic of the meeting was our first detailed discussion of NASA's Astrobiology program. The committee was very pleased to hear from Barry Blumberg, the Director of the NASA Astrobiology Institute (NAI), whose experience, strategic vision, and hands-on approach are greatly enhancing this effort. ***We were impressed by the intellectual richness of the investigations underway within the NAI, and we feel strongly and unanimously that the NAI shows great promise.*** We encourage expansion of the virtual collaboration and communication among member institutions, which is not yet fully realized.

Because Astrobiology has become so important to the Space Science Enterprise, ***we recommend that an SScAC Astrobiology Task Force be formed*** to take a more careful look at a wide range of Astrobiology-related issues. Anne Kinney presented us with a draft charter and terms of reference for this task force, and we will work with her and you to help finalize these over the coming weeks.

At our February 1999 meeting, the SScAC learned of preliminary discussions regarding a possible National Astrobiology Research Laboratory to be constructed at Ames Research Center. Our letter to you following that meeting expressed reservations about the justification for such a laboratory, and about the possibly deleterious effect that such a facility might have on the NAI.

Since then, Ames has convened two workshops to identify possible astrobiology-oriented uses for such a facility. We understand that an independent Science Definition Team (SDT) has been appointed to review and assess these potential uses by mid summer. Our Origins Subcommittee received an interim briefing from the chair of the SDT, and reported that ***a strong astrobiology-related imperative for this potential facility has not yet emerged***. We would like to hear the SDT's final findings at our next meeting.

If the SDT finds a compelling rationale for a national astrobiology laboratory, ***we recommend that their findings be provided to the proposed SScAC Astrobiology Task Force for evaluation and recommendation***. The Task Force would then assess these from an overall Astrobiology programmatic perspective, consistent with its charter and terms of reference.

If OSS proceeds with the establishment of such a laboratory after this process is completed, ***we strongly recommend that selection and long-term funding be conducted competitively through an Announcement of Opportunity or a NASA Research Announcement***. We also urge that in addition to scientific excellence, the criteria for competitive selection should include relevance to the OSS Strategic Plan.

Solar Probe

Another topic that we heard about was the continuing progress of the Outer Planets/Solar Probe program. Two years ago consideration of the scientific, technological and programmatic issues led SScAC to endorse a launch of Solar Probe in 2007. Selection of this date was driven by science requirements to encounter the sun during extremes in the solar cycle. *We reiterate*

our support for preservation of the 2007 launch date for Solar Probe even if the launch dates for the Europa Orbiter and/or Pluto/Kuiper Express are changed.

Gravity Probe-B

The Committee was unhappy to learn from you of new difficulties in the Gravity Probe-B project, including a sustained high level of risk, recurrent schedule and cost issues, and significant technical obstacles with uncertain outcomes. You described to us several recovery options, including delays and/or cancellation of other OSS initiatives, or a termination review. We understand that there is not an immediate need to choose among these options. However***, if you ultimately determine that completion of the GP-B development would be too damaging to the overall OSS scientific program, we agree with you that the option of a termination review for GP-B should be exercised.*** Because of the significance of GP-B to the overall OSS program, we request that we be briefed in more detail on its status at the next SScAC meeting.

Research Program

We heard from Guenter Riegler about the current state of the OSS Supporting Research and Technology (SR&T) program. We commend Guenter for his innovative approach to reorganizing the program into a small number of research clusters as a means to focus and reshape it. This approach appears to offer a way of assuring that OSS-funded research is current and world class, as well as coupled to and integrated with the OSS Strategic Plan. It also serves to match the management of the program with the available civil service and IPA staffing. The plan has now been endorsed by all of the SScAC subcommittees and ***we enthusiastically echo that endorsement.***

One point that received some discussion was that NASA sometimes does not highlight the accomplishments of its SR&T program to the same extent that it does the accomplishments of flight projects. Scientific research conducted with NASA data and with NASA funding is one of the most important products that the Agency generates. We therefore urge the Space Science Enterprise to highlight exciting new research results aggressively in its dealings with the news media, the Congress, and so forth.

Strategic Planning

Marc Allen updated us on progress in the writing of the next version of the OSS Strategic Plan. The work appears to be going very well, and Marc and the other authors are to be commended for their continuing efforts. SScAC members are reviewing the plan draft individually, and will forward comments and suggestions to Marc for consideration. Once the detailed content and structure of the plan are firmly established, we think that the text will benefit from an end-to-end editing that raises the excitement level of the prose to something more commensurate with the exciting program the plan discusses.

That summarizes the results of our meeting. Please don't hesitate to contact me if you would like any clarification or further detail on any of the points I've raised above.

Best wishes,

Steve Squyres
Chair, SScAC

cc: SScAC
B. Parkinson
L. Garver
J. Rosendhal
J. Alexander

21 Oct 99

MEMORANDUM FOR: Dr. Steve Squyres
Space Science Advisory Committee (SScAC)

FROM: Dr. Daniel Hastings, MIT
Christine Anderson, AFRL
Cochairs, Task Force for Technology Readiness

SUBJECT: NASA Technology Readiness in Space Science

1. The NASA Task Force on Technology Readiness conducted a readiness review of near (2007)and far (2015) technology in support of the NASA Space Science Strategic Plan in September 1999. While we did not review all the space science technology that is being funded by NASA, we did hear what NASA perceives as the enabling technology investments. The technology review was conducted in light of four questions (Atch 1). The overall sense of the committee was while many of the technology development programs were appropriate, valuable, and necessary; there were several issues.

a. First, the technology development was substantially underfunded relative to Structure and Evolution of the Universe (SEU) and Sun Earth Connection (SEC) themes/requirements. This should be addressed by greater integration of technologies between themes. For example, the SEU theme should be better integrated with the Astronomical Search for Origins (ASO) theme.

b. Second, we found that the management structure for the technology was byzantine. The lack of a clear process owner enables things to fall between the cracks. Thus it was clear that there was a gap in support between crosscutting enterprise support and focused theme work. The committee was surprised to note that many of the NASA attendees found out themselves where NASA funding was being focused at the review. This clearly indicates a lack of strategic management and communication. The committee recommends that a strengthened, simplified process be put in place. The committee strongly supports the return of the New Millennium Program, but one that is focused on technology development with greater partnership.

c. Thirdly, the committee was excited to hear the NASA presentation on the Intelligent Synthesis Environment. This has the potential for changing the design and cost paradigm for space science missions. However, the program as structured has diffuse goals and no metrics. The committee felt that the key issues in intelligent synthesis revolved around the intellectual investment rather than bolting together software packages. The committee recommends that it should be tied to a space science mission that needs it. This will help the mission and focus the program.

d. Fourthly, the committee felt that not enough attention was being paid by NASA management either at HQ or at the Center level in the development of infrastructure to support space science. The committee felt that there was no strategic view of infrastructure development. There was no presentation on planetary protection, internet-like communications through space within the Jovian orbit,

and no discussion of the impact of information technology on space science. Bottom line: the larger context is missing.

e. Lastly, the knowledge of what other agencies were doing was sporadic. Some of the poorly funded programs had excellent knowledge (possibly by necessity), but other programs seemed completely unaware of very similar thrusts in the Air Force and NRO. It was clear that there is no management culture which forces program managers to look outside their immediate environs. It appears that partnering is not a highly regarded way of doing business in some centers. This culture must be changed to spend the taxpayers' money more efficiently.

2. The committee felt this was a valuable exercise and recommends that a broad periodic technology review be made a routine part of NASA Space Science planning, just as the DOD has done with Scientific Advisory Board reviews. Specific comments on the four theme areas are described in attachment 2.

//signed//

CHRISTINE M. ANDERSON, SES
Director
AFRL, Space Vehicles

DANIEL HASTINGS, PhD
Professor, Aeronautics and Astronautics
MIT

NASA Task Force on Technology Readiness Review Questions

QUESTIONS:

1. Have missions and visions been articulated sufficiently to drive technology objectives and capabilities?

2. Have technology objectives and capabilities been described appropriately for missions and visions?

3. Have technology objectives and capabilities been well integrated across the four science themes into a single set of technology developments?

4. Is the technology development currently planned in the various program elements appropriately scoped, scheduled, and funded to satisfy the strategic missions and visions of the Space Science Enterprise?

Atch 1

NASA Task Force on Technology Readiness (TFTR) Space Science Theme Review

1. Astronomical Search for Origins

Question: Have missions and visions been articulated sufficiently to drive technology objectives and capabilities?

The ASO program has done an excellent job at articulating the missions and visions to drive the technology. In fact, NASA is doing a much better job at articulating these missions to the public through programs on PBS, TLC, and TDC. Both the missions and technologies are ambitious and a good match to NASA's goal of aggressively advancing science and engineering. The TFTR was particularly impressed, given the relatively new Origins theme, by how certain missions were articulated a decade ago in order to drive technology development and how that vision stayed on track through periods of highly variable technology funding. This latter point verifies the strength of that vision.

Question: Have technology objectives and capabilities been described appropriately for missions and visions?

ASO presented a very quantitative and comprehensive set of technology objectives, capabilities and requirements. Again, it is apparent that ASO has struck a very difficult yet appropriate balance between aggressive yet achievable technology goals. In particular, most if not all of the technologies presented provide new capabilities. This is in contrast with technologies which yield modest improvements to current technologies. This is the very definition of breakthrough.

Question: Have technology objectives and capabilities been well integrated across the four science themes into a single set of technology developments?

CETDP has identified some of the technologies that are crosscutting, but its success at integration across themes has yet to be demonstrated. There seem to be multiple optics and detector programs which are not integrated.

Question: Is the technology development currently planned in the various program elements appropriately scoped, scheduled, and funded to satisfy the strategic missions and visions of the Space Science Enterprise?

Clearly, ASO technology is appropriately scoped and adequately funded, but schedule and exit criteria (possible descoping of proposed missions) are concerns.

Atch 2

2. Structure and Evolution of the Universe (SEUS)

Question: Have missions and visions been articulated sufficiently to drive technology objectives and capabilities?

Both the Near-Term and Vision missions for the SEUS theme have been well described and with sufficient detail to derive the required technology development areas.

Question: Have technology objectives and capabilities been described appropriately for missions and visions?

The report to the TFTR by the SEUS technology representative contained a good description of the technology objectives and technology capabilities that will be necessary to carry out the Near-Term and Vision missions. The funding levels and schedules for different TRLs were not always credible.

Question: Have technology objectives and capabilities been well integrated across the four science themes into a single set of technology developments?

The technology objectives and technology capabilities required by the SEUS theme clearly identified cryogenic coolers and precision formation spacecraft flying and metrology as cross-cutting technology common to several themes. This was more explicitly spelled out in the Origins and SEUS themes than in the Sun-Earth Connection and Planetary Exploration themes.

Question: Is the technology development currently planned in the various program elements appropriately scoped, scheduled, and funded to satisfy the strategic missions and visions of the Space Science enterprise?

The technology development currently funded and projected for funding in the various program elements is quite uneven, with Origins and Planetary receiving the lions share of the budget. Within the SEUS theme there are areas that require much more funding to reach the necessary TRLs to make the projected new start schedules in the 2007 time frame, such as LISA and Con-X.

3. Sun Earth Connection

DISCUSSION

Question: Have missions and visions been articulated sufficiently to drive technology objectives and capabilities?

The "Vision" and accompanying four "Quests" defined for the SEC Program are visionary, relevant, aggressive, and present significant challenges. The definition of SEC Key Capabilities and the coupling of enabling technologies to mid- and far-term mission targets appear satisfactory.

Question: Have technology objectives and capabilities been described appropriately for missions and visions?

It is believed that satisfactory completion of the SEC Program objectives would be of significant value to NASA, the US military, and US commercial space applications.

Question: Have technology objectives and capabilities been well integrated across the four science themes into a single set of technology developments?

The briefings of the six SEC Technology Programs generally left much to be desired from the perspective of assessing technology readiness, however. As a result, the Task Force concluded that it was not possible to reasonably assess technology readiness for the SEC Technology Program at this time.

Question: Is the technology development currently planned in the various program elements appropriately scoped, scheduled, and funded to satisfy the strategic missions and visions of the Space Science enterprise?

The Task Force concluded that the various briefings generally did not convey an adequate understanding of the technology programs proposed. Further, the substantial risk inherent in such aggressive, challenging activities was not discussed in any depth nor was a substantial approach to risk mitigation presented. Consideration of potential alternate approaches to achieve mission requirements was generally not discussed. The presentations of funding requirements and plans appeared superficial and idealistic. Cognizance of similar work being performed elsewhere appeared inadequate.

4. Exploration of the Solar System

Question: Have missions and visions been articulated sufficiently to drive technology objectives and capabilities?

The Solar System Exploration theme is both blessed and cursed with a plethora of planned and potential future missions, which are only now starting to be prioritized and planned beyond the current funding allocations. This theme also seems to be focused almost entirely on the larger (and more ambitious) missions, assuming the Discovery program will pick up the missions capable of being performed within that program's limitations. The most glaring omission in this area is the total lack of planning for Mars exploration beyond the Ô03/Õ05 sample return missions. The Task Force was told this was due to the pace and pressure of the sample return missions preventing a focused effort for longer-range planning; while understandable, this is a huge component of SSE (in terms of science return, monetary investment, and public interest), and its absence severely hampers an assessment of overall technology planning.

Question: Have technology objectives and capabilities been described appropriately for missions and visions?

This theme prefaced their presentation by stating that they had chosen to cover only a selected set of technology areas that were judged to be in "good shape". It is true that SSE mission objectives have (arguably) a wider range of applications, and therefore required technologies, than any of the other three themes. This necessarily limited the scope of presentations under this area. However, an overall assessment indicates that those technology objectives and capabilities presented were necessary and appropriate for the relevant missions. There was no real indication that the missions and visions had been used to drive out a comprehensive set of technology objectives. The Task Force assumes that this has been done, but was not presented due to its complexity and the time restrictions of the review meeting.

Question: Have technology objectives and capabilities been well integrated across the four science themes into a single set of technology developments?

While there is some commonality with other themes, the focus on both in-situ and sample return missions create unique requirements for SSE technology to enable many of the planned and potential missions. Several of the thrust areas of the Cross-Enterprise Technology Development Program (e.g., Surface Systems, In-Space and Atmospheric) are only applicable to SSE missions. Those technology areas SSE shares with other themes (e.g., spacecraft power, propulsion, gossamer spacecraft for solar sails) seem to be well integrated, although it appears that technology development funding is still organized and tracked specific to themes, rather than in a more global management structure.

(It should be noted that the "management structure" of the entire technology development effort was perhaps the most confusing element of the entire review process, particularly with presentation hopping around between conceptual, cross-cutting, and focused programs, without clear indications of how (or whether) these programs actually coordinate their planning activities.)

Question: Is the technology development currently planned in the various program elements appropriately scoped, scheduled, and funded to satisfy the strategic missions and visions of the Space Science enterprise?

It appears that the limited set of technology development programs presented are well-funded and aimed at supporting relevant missions in an appropriate time frame for technology infusion. Several points, either explicit or implied, were of concern to the Task Force:
There seemed to be a limited understanding of systems-level optimization in the presented material, particularly in terms of synergy among technologies. For example, a discussion of future applications of solar-electric propulsion did not take into account realistic advances in solar array technologies also funded by this program.
There was an overall attitude of "advanced technology is good", rather than a quantitative analysis of where advanced technology infusion would be most effective. For example, the overview of Mars exploration discussed a requirement (apparently imposed from above) that all post-2005 missions would incorporate "creative far-out technologies", with "no incremental improvements". It is not clear that this approach is appropriate for maximizing the science return from Mars exploration.
A number of technology development areas appeared to be limited in scope, without any explanation or supporting information. For example, aerobraking/aerocapture was identified as a critical technology for future planetary missions, but the only approaches under consideration (with repeated questioning) were ballistic aeroshells and ballutes. Recent experience with Mars Climate Observer would strongly indicate the utility of a lifting aerodynamic configuration to provide flexibility for recovering from off-nominal trajectories at entry interface.
There was some verbal expression of support for in-situ resource utilization, but there appears to be no resources allocated to support technology development in this area.
There was no overview of all funding sources and how they interacted to support the programs presented. This would have been greatly helpful to the Task Force to provide context for some of the decisions made.